

HVAC TESTING AND BALANCING (commissioning not included)

DOCUMENT NUMBER: 15305

APPLICATION: ELEMENTARY, MIDDLE AND HIGH SCHOOL

DATE OF ISSUE:

- 12-05-14** - **Miscellaneous clarifications, incl. revised design deviation tolerances**
- 05-04-11** - **Miscellaneous clarifications and requirements for additional equipment**
- 11-08-10 - Revised Paragraph 1.6B
- 01-12-10 - First Issue

NOTES:

The Contractor is to provide a final Testing and Balancing Report in accordance with the attached specification **upon or before achieving** Substantial Completion of the project or phase of the project (refer to paragraph 1.4.D).

The **Design Professional (A/E of Record)** will review and recommend acceptance of the system, **in writing**, based on this final report.

ATTACHMENTS:

HVAC Testing and Balancing Specification, dated **12-05-2014**

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Drawings and general provisions of Contract, including General and Supplementary Conditions, of this specification division, Division 1 specification sections and the Commissioning Specification apply to work of this Section.

1.2 TESTING AND BALANCING OF HVAC SYSTEMS

- A. Selection: The Construction Manager or Prime Contractor, herein referred to as Contractor, shall procure the services of and **contract directly with** an independent Test and Balance contractor (Balancer), who specializes in the testing and balancing of heating, ventilating, and air conditioning systems. The Balancer shall test, balance and adjust all water circulating and air moving equipment, air distribution, and exhaust systems, and temperature control equipment and systems as herein specified and shown on the drawings.
- B. The Contractor shall award the test and balance contract to the Balancer as soon as possible to allow them to schedule the work in cooperation with other trades and to meet the completion date. The Contractor shall prepare a critical path schedule, coordinated with all subcontractors, so as to accomplish all tasks required of the Balancer as scheduled herein.
- C. Refer to specific items of work provided by each installer, and outlined in the paragraph entitled, "CONTRACTOR'S RESPONSIBILITIES". Contractor shall cooperate with the Balancer as required during execution of the work under this section.
- D. The Balancer shall inspect all work under the above sections as it relates to work under this section and report in writing to the Contractor and **Design Professional** any deviations from plans and specifications that will affect the performance of the systems. All correspondence (written, fax, electronic mail, and the like) is to be copied to the Testing and Commissioning **Contractor (Commissioner)** that is directly contracted by the Owner.
- E. **Design Balance Deviation Tolerances**
 - 1. **All HVAC systems (water and air) shall be balanced to within +/- 5% of design, except as follows:**
 - a) **Supply fans with design airflow less than 100 CFM and all exhaust fans shall be balanced from 100% to 110% of design.**
 - b) **Air distribution devices with design airflow less than 100 CFM shall be balanced to within +/- 10% of design.**
 - c) **Set pumps to operate from 100% to 105% of design flow.**
 - 2. **Each form presented in each report shall include a column indicating the amount of deviation, expressed as a percentage (%) of the design value.**

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1.3 BALANCER QUALIFICATIONS

- A. The Balancer shall be a member in good standing with The Associated Air Balance Council (AABC) or National Environmental Balancing Bureau (NEBB) and shall provide [a National Project Certification Performance Guaranty to the Owner](#). The Balancer must be totally independent, having no affiliation with any contractor, **Design Professional**, or equipment manufacturer/supplier of HVAC related equipment.
- B. The Balancer shall have a fully staffed office and have been regularly engaged in the testing and balancing of heating, ventilating, and air conditioning systems.
- C. The Balancer shall provide proof that personnel performing work have successfully completed at least five (5) projects of similar size and scope. A complete list of reference projects, including name and phone number of contacts, shall be submitted with the bid.
- D. All instruments used shall be accurately calibrated within six months of balancing and maintained in good working order. If requested, the test shall be conducted in the presence of the **Design Professional** and/or his representative.

1.4 BALANCER SUBMITTALS

- A. Provide a testing and balancing plan for review within thirty days upon receipt of contract. The plan review should include comments and recommendations on any discrepancies that may hinder balancing. This plan review shall be transmitted directly to the Contractor.
- B. Submit to Contractor equipment pre-start and start-up forms. After receipt from the contractor of the submittal data, forms will be transmitted by the Balancer to the Mechanical Contractor for use in equipment start-up. The completed forms will be turned over to the Balancer prior to the beginning of the test and balance phase.
- C. Submit agenda of test procedures for each system, describing balancing standards for the testing and balancing of the air conditioning, heating, and ventilating systems for the approval of the **Design Professional**. This agenda shall include all forms for each system and component, with specified data from the project plans and specifications included on the forms.
- D. The Final Testing and Balance Report, with the **Design Professional's** letter of acceptance, must be received by [the Owner's Project Coordinator no later than 30 days after Substantial Completion inspection](#). **Allow no less than 10 days for Design Professional's review.** (See also paragraphs 1.6.B and 3.1.B.)
- E. **The Final Testing and Balance Report shall indicate any design requirements which were modified after the issuance of the original Construction Documents. Such indication(s) shall include the date on which the requirement was changed and shall reference the particular Contract Document (i.e., Addenda, Change Order, Construction Change Directive, etc.) which effected the change. (Changes made without Owner's written approval are invalid.)**

1.5 BALANCER MEETINGS, INSPECTIONS AND TESTS

- A. Make inspections of the systems during construction for proper installation of balancing devices and general construction as related to HVAC testing and balancing work. The number of inspections will vary with size and complexity of the project, but a minimum

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of two inspections is required: one at 50% completion of ductwork installation, the second at 80% completion of ductwork installation. A written report of each job visit shall promptly be sent to the Contractor for transmittal to the Design Professional, and shall be included in the Final Test and Balance report.

- B. Perform Final Test and Balance work associated with the HVAC system as described herein.
- C. A minimum of one after-occupancy inspection shall be made 90 days after the final test and balance. At this time, any minor adjustments shall be made for occupant comfort. Major problems, which will require major readjustments, shall be addressed to the Design Professional prior to any readjustments. Any alterations to the final test and balance report shall be transmitted as a revised report to the Construction Manager for transmittal to the Design Professional.

1.6 BALANCER WARRANTY AND REPORTS

- A. Provide National Project Certification Performance Guarantee. This Performance Guarantee is to be either by NEBB or AABC. Depending on which organization is chosen, the report is not to mention, or include reference to the other organization.
- B. The Owner will not delay acceptance of the HVAC system due to lack of an approved T&B report clear of any deficiencies. If the approved report isn't submitted within 30 days after substantial completion date, liquidated damages will be assessed.
- C. Submit to the Design Professional (A/E) five (5) printed copies and one (1) electronic copy of tabulated reports in neatly organized typed forms (with numbered pages) with AABC or NEBB approved minimum data, within fifteen working days after completion of test. Report will include start-up reports, equipment test data and drawings to coincide with the test report. In addition, all reports shall incorporate a summary page(s) which shall include:
 - 1. General description of project (building type, system type, equipment description, etc.)
 - 2. A descriptive list of all equipment and test results (sorted building by building) which do NOT meet plans and specifications. All equipment and test data NOT listed on the above mentioned summary page(s) will be considered to perform within the design balance deviation tolerances specified in Paragraph 1.2.E.
 - 3. Copies of reduced plan drawings that uniquely identify and cross reference air devices, VAV boxes, dampers, equipment, etc.
 - 4. Duct pressure test/leakage and Hydrostatic leakage test reports.
 - 5. Building Pressure tables, design and actual.
 - 6. Start-up reports.
 - 7. Inspection reports.

Any report which the Design Professional determines is inaccurate or incomplete shall be returned to for correction, completion, or retesting. Revised reports shall be submitted in their entirety – partial reports will not be accepted. Each revision shall be highlighted and shall indicate the revision date. The cover page shall indicate the date of the first edition and the revision date.

- D. The Owner reserves the right to obtain verification of the test and balance reports. Such verification shall be performed by a second independent contractor. Balancer's reports found to be inaccurate will be disallowed and the Balancer will be required to repeat operations under the supervision of the second independent contractor until accurate reports are completed and agreed upon. The cost of the verification will be borne by the Owner, unless the Balancer's initial report is found to be inaccurate. In

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such case, the costs of the verification test and balance and all subsequent costs of supervision in order to secure acceptable reports will be borne by the **Balancer**.

PART 2 - PRODUCTS (not used)

PART 3 - EXECUTION

3.1 CONTRACTOR'S RESPONSIBILITIES

- A. Final testing and balancing of the HVAC systems shall be performed as specified above. It is the responsibility of the Contractor to be completely familiar with all the provisions and responsibilities of the Balancer, and to provide such certification, cooperation, and support required.
- B. The Contractor shall **correct or** repair all deficiencies noted by the Balancer in a timely manner. The Balancer will notify the Contractor in writing, on a daily basis, of any deficiencies discovered. Contractor will notify the Balancer immediately, in writing, upon completion of the **corrections or repairs**. **If any items certified as having been corrected or repaired are found to remain deficient, the Contractor shall thereafter be responsible for additional costs incurred by the Balancer and the Design Professional, including but not limited to repeated inspections, tests and document reviews, until such items are individually either deemed compliant or accepted in writing by the Owner. *The final testing and balancing report will contain no punch list items. All deficiencies will have been corrected prior to submission of the final report. Preliminary reports are not to be submitted to the Owner.***
- C. The Contractor shall:
 - 1. Allow adequate time in the construction schedule to perform the Testing and Balancing work.
 - 2. Notify the Balancer upon commencement of work related to the HVAC system.
 - 3. Provide required shop drawings and equipment data.
 - 4. Provide test openings as required for testing and balancing HVAC systems.
 - 5. Provide updated job schedule and timely notice prior to scheduled events.
 - 6. Provide test openings and temporary end caps or otherwise seal off ends of ductwork to permit leakage testing prior to installation of diffusers, grilles, and similar devices.
 - 7. Make preliminary tests to establish adequacy, quality, safety, completed status, and satisfactory operation of HVAC systems and components. The systems shall be free of electrical grounds and short circuits.
 - 8. Perform duct leakage tests, in the presence of the Balancer, on all supply, return, outside air make-up, and exhaust air systems.
 - 9. Within the intent of the contract documents, provide, at the request of the Balancer, all equipment, material, supplies, workmen, and supervisions necessary to provide a satisfactory, operating system.
 - 10. During the test and balance period, operate all HVAC equipment as necessary to permit systems to be tested and balanced as fully operating, functional systems.
 - 11. Work harmoniously with the Balancer, providing all courtesies normally extended to professional consultants.
 - 12. Perform all work necessary to make ceiling plenums air-tight and functional.
 - 13. Remove and replace ceilings as necessary to permit test and balance operations.
 - 14. Remove and replace equipment, lights, or other items which obstruct testing and balancing operations. Where equipment, lights, or other items will interfere with future adjustments of the HVAC system, such equipment, lights, or other items shall be relocated by the Contractor, as directed by the **Design Professional**.
 - 15. Provide completed start-up forms on each piece of equipment.

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16. Replace belts and drives as required for proper balancing. Drives shall be adjusted and aligned by the Contractor to prevent abnormal belt wear and vibration.
 17. Adjust fan speed as required not to exceed RFLA of motor.
 18. Open all manually adjustable dampers and test dampers for smooth, vibration-free operation.
 19. Verify that all controls are installed and operating in accordance with the sequence of operation.
 20. Before requesting final testing and balancing, submit signed statement that HVAC systems are installed, adjusted, fully lubricated, operating satisfactorily, and are ready for use.
- D. Duct Leakage Report: The Contractor shall make all the supply, return, outside air, and exhaust duct systems (limited to 1,500 cfm and greater) operationally air-tight, with no more than 2% leakage for duct systems rated at 2" w.c. pressure class, and 1% leakage for systems exceeding 2" w.c. pressure class. Leakage test to be performed by Contractor with all air device openings and fan connections sealed airtight. Test the systems prior to applying any insulation or concealing in soffits or chases. Use a portable fan capable of producing a static pressure equal or greater than the duct test pressure. This fan to have a flow measuring assembly consisting of a straight section of duct with an orifice plate, pressure taps, and a calibrated performance curve for determining leakage rates.
1. Test each section equal to the external static pressure indicated for that fan or air handler with the portable fan assembly. After the fan achieves that steady state design pressure, record the air flow quantity across the orifice and the percent of design air flow. If the test fails, the Contractor shall reseal and retest at no additional cost to the District.
 2. Repair all duct leaks that can be heard or felt, even if the system has passed the leakage test.
 3. Submit duct leakage reports to the Balancer and the **Design Professional** for their review and approval.

3.2 BALANCER'S RESPONSIBILITIES

- A. Air Balance: The Balancer shall perform the following tests, and balance system in accordance with the following requirements:
1. Record minimum data required by AABC and NEBB forms.
 2. Test and adjust fan rpm to design requirements.
 3. Test and record motor full load amperage/voltage and operating amperage/voltage.
 4. Make pitot tube traverse of main supply, return, OA and exhaust ducts and obtain design cfm at fans. The air flow in rectangular duct shall be traversed and measured using the log-Tchebycheff method and round duct shall be measured with the log-Linear method (a.k.a. log-Tchebycheff), no exceptions. Refer to the AABC's 1989 National Standards Manual Chapter 8; NEBB's latest Procedural Standards, Section 10; and ASHRAE's 1997 Fundamentals Handbook Chapter 14.
 5. Test and adjust system for design cfm recirculated air.
 6. Test and adjust system for design cfm outside air.
 7. Test and record system static pressure profile.
 8. Adjust all main supply and return air ducts to proper design cfm.
 9. Adjust all zones to proper design cfm, supply, return, and exhaust.
 10. Adjust all VAV terminals to design minimum, maximum and/or heat cfm and record controller setpoint.
 11. Provide suggestion/corrective measures pertaining to performance related issues.
 12. Test and adjust each **air distribution device to operate within tolerances specified in Paragraph 1.2.E.**
 13. Each grille, diffuser, and register shall be identified as to the location, area, and system.

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14. Test and adjust fans to operate within tolerances specified in Paragraph 1.2.E.
 15. Test and adjust kitchen hoods and fume hoods. Traverse exhaust duct. Seal test holes through the duct access panel with flat head bolts inserted from inside of duct.
 16. Provide a Table in the report that itemizes all the Outside Air Make-up cfm compared to all the Exhaust Air cfm (specified and actual) that is to demonstrate that the building is experiencing a continual positive pressure. There is to be one Table per building.
- B. Size, AK catalog factors of diffusers, grilles, registers, and all tested equipment shall be identified and listed.
 - C. Readings and test of diffusers, grilles, and registers shall include required fpm velocity and test resultant velocity, required cfm, and and test resultant cfm after adjustments. When direct cfm measuring instruments are used, velocities are not required.
 - D. In cooperation with the controls contractor, set adjustments of automatically operated dampers to operate as specified, indicated, and / or noted.
 - E. Check all controls for proper calibrations, and list all controls requiring adjustment by control installers.
 - F. All diffusers, grilles, and registers shall be adjusted to minimize drafts in all areas.
 - G. Witness and record the testing of the ductwork for leakage to insure proper sealing. The Balancer shall randomly select sections of the completed duct system for testing. The sections selected shall not exceed more than 20% of the measured linear footage of supply, return, exhaust or plenum duct length. All selected ductwork shall be leak tested in accordance with SMACNA. Maximum allowable leakage at any tested section shall not exceed 2% of the total air. If any of the selected duct sections exceed the specific leakage allowance, those sections shall be repaired by the Contractor and retested by the Balancer. If initial testing exceeds specification allowance, testing of all remaining duct ductwork shall be required at the Contractor's expense. All additional costs for duct leak repair and retesting shall be the responsibility of the Contractor.
 - H. Advise Contractor in writing of all ductwork that shall be repaired to reduce air leakage. Retest to confirm minimum allowable leakage. The cost of retest of failed systems will be the responsibility of the Contractor.
 - I. Water Balance: The Balancer shall prepare the water systems for balancing in the following manner:
 1. Open all valves to full open position. Close all bypass valves. Set modulating valve to full coil flow.
 2. Check all strainers where gauge taps are provided, and if required, direct Contractor to clean same.
 3. Examine water in system and determine if the water has been treated and cleaned. If water has mud or other entrained matter, test and balance work shall stop and Contractor shall clean system as specified in other sections of this Division 15 specification.
 4. Check pump rotation.
 5. Check expansion tanks to determine that they re not air-bout and that the system is completely full of water.
 6. Check all air vents at high points of water systems and determine all are installed and operating freely.
 7. Check coils for counterflow or parallel flow as called for by design.
 8. Set all temperature controls so all coils are calling for full cooling or heating. This should close all automatic bypass valves at coils.

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9. Check operation of automatic bypass valves.
 10. Check and have control contractor set operating temperatures of chillers / boilers to design requirements.
 11. Complete air balance must have been accomplished before actual water balance is complete.
- J. Chilled Water/Hot Water:
1. Set pumps to 100%-105% of design flow.
 2. Adjust flow of water through chillers / boilers.
 3. Check leaving water temperatures and return water temperature through chillers / boilers. Reset to correct design temperatures.
 4. Check water temperature at inlet side of coils.
 5. Proceed to balance each water coil. Upon completion of flow readings and adjustments at coils, mark all settings and record data.
 6. After adjustments to coils are made, recheck settings at the pumps and chillers / boilers, and readjust if required.
 7. All flow devices to be balanced to within +/-5% of design.
8. Record and check the following items at each cooling / heating element:
- a. Test and record entering air temperature (DB heating and cooling).
 - b. Test and record entering air temperatures (WB cooling).
 - c. Test and record leaving air temperatures (DB heating and cooling).
 - d. Test and record leaving air temperatures (WB cooling).
 - e. Entering and leaving water temperature.
 - f. Pressure drop of each coil or vessel.
 - g. Calculate gpm.
 - h. Calculate total cooling and heating coil capacities.
 - i. If test conditions are not within design tolerance, then convert the test conditions to design conditions, or re-test when conditions are closer to design (i.e. opposite season test).
- K. Chiller Performance Test: Test chiller in accordance with ARI Standard 83-550.
- L. Cooling Tower Performance Test: test cooling towers in accordance with CTI Code ATC-105.
- M. Record The Dry Bulb Temperature in each space and in addition, record a wet bulb temperature at each thermostat or sensor.
- N. Deficiencies: All deficiencies shall be noted by the Balancer in a field report and submitted to Contractor and the **Design Professional** on a daily basis. All deficiencies will be uniquely numbered and tracked.
- O. Upon correction of deficiencies, the Contractor shall notify the Balancer in writing that the problem is resolved. If any deficiencies are not corrected, the Contractor will be responsible for the cost of additional re-testing.
- P. Equipment: All information required as shown, but not limited to, shall be compiled in a neat, orderly, itemized format on 8½" x 11" test forms. The following data shall be submitted to the Contractor, for distribution to the **Design Professional** and Owner. This data is the minimum required data except where specified standard (i.e. AABC) requires additional data. In addition, any HVAC equipment specified for the project, but not indicated below, is required per AABC form.

Air Handlers, Fan Coils, And Duct-mounted Coils:

1. Mark number

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2. Unit manufacturers and model number
3. Total supply air cfm and rpm - specified and actual
4. Return air cfm - specified and actual
5. Outside air cfm - specified and actual
6. Unit static pressure profile, including total fan static
7. Specified total and external static pressure
8. Water gpm flow, coil pressure drop, and entering and leaving temps - specified and actual
9. Coil - entering and leaving air DB/°F and WB/°F - specified and actual
10. Outside air DBF and WBF at time of test
11. Voltage, phase, and cycle specified load conditions
12. Hand calculations of the BTUh at test conditions of Total cooling, Latent cooling and Sensible cooling.

Pumps:

1. Mark number
2. Manufacturer and model number
3. gpm flow - specified and actual
4. Shut-off head
5. Pump heat and full load amperage - specified and actual
6. Motor hp - specified and actual
7. Voltage, phase, and cycles - specified and actual

Fans:

1. Mark number
2. Manufacturer and model number
3. Total cfm supply and rpm - specified and actual
4. Static pressure (discharge static - suction static)
5. Full load amperage - specified and actual
6. Voltage, phase, and cycles - specified and actual

Air Devices (grilles, Registers, Diffusers, and Louvers):

1. Mark number
2. Room number
3. cfm - specified and actual
4. Size
5. Effective area
6. Velocity FPM - specified and actual

Chiller ([edit for air cooled or water cooled](#)):

1. Mark number
2. Unit manufacturer and model number
3. Total chilled water and condenser water gpm - specified and actual
4. Chilled water entering and leaving temperature - specified and actual - one hour log
5. Cooler and condenser pressure drop - specified and actual
6. Compressors full load amperage - specified and actual
7. Voltage, phase, and cycle - specified and actual
8. Ambient temperature, DB/WB, time of day, and weather conditions at time of test
9. Cooler tons, condenser tons, and operating kW compared to specified conditions

Cooling Tower:

1. Mark number
2. Manufacturers
3. Model number
4. Size and serial number
5. Motor hp and rpm

6. Voltage, phase, hertz
7. Full load amps
8. Running amps
9. Air on WB - one hour log
10. Air off WB - one hour log
11. Cold water off °F - one hour log
12. Specified and actual tons capacity at design conditions (15,000 Btu per hour per ton)

Variable Air Volume Boxes:

1. Mark number
2. Unit manufacturer and model number
3. Location and room number
4. Air handler number
5. Maximum / minimum and heating supply cfm - specified and actual
6. For DDC controls: measure and record computer readout and calibration factor at design conditions.
7. Electric heat, KW – specified and actual
8. Electric heat, °F entering and leaving – specified and actual.
9. Voltage, phase and cycles – specified and actual

Hot Water Boiler:

1. Mark number
2. Unit manufacturer and model number
3. Capacity bhp - specified and actual
4. Heating water flow gpm - specified and actual
5. Water temperature enter and leaving - specified and actual
6. Water pressure entering and leaving - specified and actual
7. MBtuh Input / output - specified and actual.
8. MBtuh output - specified and actual
9. Gas burner
10. Gas inlet pressure, in wtr
11. Blower motor hp and FLA
12. Fire rate - gas, therm.
13. High fire set point
14. Low fire set point

Air Monitor:

1. Mark number
2. Unit manufacturer and model number
3. Duct size/monitor size factor
4. cfm - specified and actual.
5. velocity and velocity pressure

Water Flow Stations:

1. Mark number.
2. Unit manufacturer and model number.
3. Size.
4. GPM specified and actual.
5. Pressure drop and setting.

Heat Exchangers:

1. Mark number.
2. Unit manufacturer and model number.
3. gpm secondary flow and pressure drop – specified and actual.
4. gpm primary flow and pressure drop – specified and actual.
5. inlet and outlet temperature of secondary – specified and actual.

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6. inlet and outlet temperature of primary – specified and actual.

DX Equipment:

1. Mark number
2. Unit manufacturers and model number
3. Total supply air cfm and rpm - specified and actual
4. Return air cfm - specified and actual
5. Outside air cfm - specified and actual
6. Hot Gas Reheat Coil - entering & leaving air DB/°F and WB/°F - specified & actual
7. Specified total and external static pressure
8. Cooling Coil - entering and leaving air DB/°F and WB/°F - specified and actual
9. Outside air DBF and WBF at time of test
10. Voltage, phase, and cycle specified load conditions
11. Hand calculations of the BTUh at test conditions of Total cooling, Latent cooling and Sensible cooling.

Energy Recovery Unit:

1. Mark number
2. Unit manufacturers and model number
3. Exhaust cfm - specified and actual
4. Outside air cfm - specified and actual
5. Unit static pressure profile, including total exhaust air fan static
6. Unit static pressure profile, including total outside air fan static
7. Specified and actual total and external static pressure of the exhaust and outside air.
8. Exhaust air - entering and leaving air DB/°F and WB/°F - specified and actual
9. Outside air - entering and leaving air DB/°F and WB/°F - specified and actual
10. Voltage, phase, and cycle specified load conditions
11. Hand calculations of the BTUh at test conditions of Total cooling, Latent cooling and Sensible cooling.

END OF DOCUMENT 15305